This law appears to hold over a wide range of ordinary working intensities, breaking down only for very low and for excessively intense stimulation.

Fechner proceeded further by assuming that the above constant was proportional to the corresponding increment δB to the sensation. Hence $\delta L/L = c\delta B$ and by integration

$$B = c\ (\log L - \log L_0).$$

In this form or in similar forms differing only in the choice of integration constant, Fechner's law has been accepted by psychologists for half a century.

There are two very serious if not fatal defects in this deduction. In the first place, the increments δL and δB are finite quantities and by no means infinitesimal increments approaching zero as a limit, such as would be required for such an integration. The least perceptible increment to the stimulus (δL) is determined by the sensibility of the sensory organ concerned. At the threshold value it is as large as L itself, while at moderate intensities it bears a fixed ratio to L. The value of δB is entirely arbitrary, dependent upon the unit chosen in which to measure it. It may be greater than unity in special cases. In the second place, c is not a constant but a function of L. At low intensities approaching the threshold value it varies rapidly with L.

There appears to be no direct method for overcoming these defects. A method of avoiding them altogether has however occurred to the writer and been applied to the visual case in a way that may be perfectly satisfactory to psychologist and mathematician alike.

Consider any physical instrument—a galvanometer for instance, capable of indicating on a scale the amount of an external stimulus affecting it. The derivative of scale reading with respect to the stimulus will be a measure of the sensibility of the instrument at all parts of the scale. Conversely, the general integral of sensibility will give the scale reading as a function of the stimulus.

In the visual case we have sensibility to find scale reading. The best data on sensibility are those of König and Brodhun[1] covering about twenty different intensities for each of six different wave-lengths. The writer has elsewhere[2] shown that these data may be represented by the function

$$P = \delta L/L = P_m + (1 - P_m)(L_0/L)^n$$

where P_m is the minimum value of P, L_0 is the threshold value in light units and n a number varying from one third to two thirds with wave-length. The reciprocal of the least perceptible increment δL or $1/LP$ is a measure of the desired sensibility of the eye to differences of intensity. Hence we have for the scale reading or, in this case, the visual sensation of brightness,

$$B = \int K \frac{dL}{PL} = \frac{K}{P_m} \log [1 + P_m(L^n L_0^{-n} - 1)]^{1/n}$$

where K is a constant dependent upon the unit of sensibility chosen.

This general form includes Weber's law and Fechner's law as special cases for moderate intensities, but holds for low intensities down to the threshold of vision. Weber's law $\delta L/L =$ constant may be extended to cover low intensities by writing

$$\delta L/L = P_m + (1 - P_m) L^{-n} L_0^n.$$

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BUREAU OF STANDARDS,
WASHINGTON, D. C.,
December, 1907

[1] *Berlin Sitz.*, 1888, 917–931.

[2] Bull. Bureau of Standards 3, 62.

ASTRONOMICAL NOTES

FLUCTUATIONS IN THE SUN'S THERMAL RADIATION[1]

Many scientists have attempted in the past to show that periodical fluctuations occur in meteorological phenomena, presumably dependent on changes in the solar radiations. The two most plausible periods of solar change are the sun-spot period, whose mean value is about eleven years, and the time of the synodic rotation. Professor Newcomb develops analytical methods for the investigation of fluctuations in a fixed period, and also when the

[1] Simon Newcomb, "A Search for Fluctuations in the Sun's Thermal Radiation through their Influence on Terrestrial Temperature," Transactions of the American Philosophical Society, N. S., Vol. 21, V.

period is ill marked or wanting. These methods are then applied to the determination of the relation of changes in temperature to the sun-spot period, the synodic period, and to several others.

Köppen, from a study of meteorological observations in various regions of the globe, made from 1767 to 1877, arrived at the conclusion that the temperature of the tropical regions was lower by 0°.7 C. near the time of maximum sun-spots than near the time of minimum. Brückner has more recently shown some evidence of a period of thirty-five years in meteorological phenomena, including temperature.

Professor Newcomb arrives at the following conclusions: "The reality of the 11-year fluctuations seems to be placed beyond serious doubt, the amplitude being several times its probable error." But, "Its amount is too small to produce any important direct effect upon meteorological phenomena." The fluctuation is about one half that found by Köppen, or less than half a degree Fahrenheit. The reality of the 35-year period was not established.

The above results were obtained by the use of annual mean departures. From a study of monthly mean departures the conclusion is reached that "The evidence is rather weak in favor of very minute fluctuations in the sun's radiation for periods greater than one month and less than several years. If they exist, they are too small to produce any noticeable meteorological effect." The most probable period of these possible fluctuations is about six years. "Apart from this regular fluctuation with the solar spots, and this possible more or less irregular fluctuation in a period of a few years, *the sun's radiation is subject to no change sufficient to produce any measurable effect upon terrestrial temperatures.*" Ten-day and five-day departures were also studied. "There is a certain suspicion, but no conclusive evidence, of a tendency in the terrestrial temperature to fluctuate in a period corresponding to that of the sun's synodic rotation. If the fluctuations are real they affect our temperatures only a small fraction of one tenth of a degree."

These results obtained by Newcomb are in direct opposition to results obtained by Langley and published in the *Astrophysical Journal* for June, 1904. Langley's bolometer observations appeared to show that early in 1903 a marked diminution in the solar radiation took place, amounting perhaps to about ten per cent. The bolometer results appeared to be confirmed by synchronous temperature observations at widely different stations. If Newcomb's results are accepted as conclusive, it follows that the bolometer as well as the temperature observations which Langley used were influenced by terrestrial causes, though this, in the case of the bolometer, was guarded against with extreme care. This seems the more probable since several of the meteorological stations which were used by Langley in verifying his results were in high latitudes, rather than in low latitudes, where any changes in the solar radiation would be most felt. At such stations during that year only small changes of temperature appear to have taken place.

THE RETURN OF HALLEY'S COMET

An event of extreme interest, not only to astronomers, but to the world at large, will soon take place. This is the return of the periodic comet made famous by the genius of Halley.

Before Halley's time comets had been regarded as chance visitors to our solar system, except when they were looked upon as special messengers of divine wrath. Newton, however, showed that comets were subject to the law of gravitation. By mapping the paths of many comets, Halley found that three of them apparently had the same orbit, that is, they were different apparitions of the same object. He observed this comet in 1682 and predicted its return again after 76 years. He knew that he could not live to witness the event, and his words concerning it are rightly famous: "If it should return according to our predictions, about the year 1758, impartial posterity will not refuse to acknowledge that this was first discovered by an Englishman." It returned in March, 1759, a few months later than Halley expected, and only seventeen years

after his death. Pontécoulant was one of at least five mathematicians who computed the last return of Halley's comet in 1835. It reached perihelion within a few days of the predicted time. Pontécoulant also made the necessary computations for the next return, and published his results in 1864. His date for perihelion is May 24, 1910. It was to be expected that before the time for its return various astronomers would be sufficiently interested in the problem to redetermine the elements. So far this appears to have been undertaken only by the English astronomers, Cowell and Crommelin. It is interesting to know that the results which they obtain are in substantial agreement with those of Pontécoulant, so that the comet may be confidently expected to reach perihelion passage in May, 1910. Astronomers will not wait till that time, however, for their first view of the comet. Professor O. C. Wendell has published in the February number of *Popular Astronomy* an ephemeris based on the elements of Pontécoulant. From this it appears that at the present time the comet is less distant from the sun than Saturn. Its position, in the northern edge of the constellation Orion, is favorable for observation, but it is doubtful if even the great telescopes of the present day can reach it at present. Owing to the form of its orbit and its distance, the comet is moving in nearly a direct line toward the sun, and as viewed from that luminary would appear to stand nearly stationary in the sky. Owing to the motion of the earth, however, it will sway, during the next year and a half, backward and forward on the borders of Orion, Monoceros, Gemini and Taurus. About the first of October, 1909, its apparent motion will become very rapid as it approaches the sun. After April of the present year it will be unfavorably placed for several months. Next year the conditions will be somewhat similar, except that by January, 1909, the distance of the comet from the earth will be only that of the orbit of Jupiter. By October, 1909, the distance will have decreased to about 300 millions of miles, and by that time, if not before, the comet will probably have been "picked up" photographically or visually.

The mean period of Halley's comet is 76 or 77 years, but, owing to the powerful perturbations of the great planets, this period varies much. Cowell and Crommelin state that the revolution of 1222 to 1301 was the longest on record, taking 79 years and 2 months, while the present round is the shortest, only 74 years and 5.5 months. It is believed that apparitions of this comet have been recorded during the last 2,000 years, but the identity of the earliest appearances has not yet been certainly established.

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BOTANICAL NOTES

TREES AND LIGHTNING

IN the "Notes from the Royal Botanic Garden of Edinburgh" (No. XIV.) Dr. A. W. Borthwick discusses some of the effects of lightning strokes upon various kinds of trees. He begins by referring to the "widespread popular belief that certain trees are less liable than others to be struck by lightning, and that during a thunderstorm it is quite safe to stand under a beech for example, while the danger under a resinous tree or an oak is respectively fifteen or fifty times greater." This and other questions, as of the exact nature of the injury done to the tissue of the tree, the author takes up and examines with care. He concludes with reference to the first point "that no tree is immune" since "lightning will select one species quite as readily as another," and "that the beech is struck quite as frequently as any other species." Apparently the taller trees in a neighborhood are the ones most liable to be struck. Contrary to what is believed by some people the cells are not "ruptured or torn by the formation of steam, as might happen if the heating by the electric current was very great. The cells collapse and shrink up, but are never torn." The root system does not seem to be ever damaged by lightning.

AS TO BIRDSEYE MAPLE

MANY a botanist has puzzled over the question of the nature and cause of the peculiar